Non-equilibrium chemistry models and directly imaged exoplanets with JWST/MIRI

**JWST:**
In October 2018 the JWST will be launched with four instruments on board; three instruments, will be operating in the 0.6-5 microns range: NIRISS, NIRCam, NIRSpec, and one in the 5-28 microns range: MIRI.

**MIRI:**
coronagraphy, imaging and spectroscopy
3x four Quadrants Phase Mask (4QPM) (2 for NH$_3$)
mid and low spectral resolution

**Targets:**
self-luminous planets (young and hot) faraway from the host star

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**Goal:** How JWST (especially MIRI) can help to characterize atmosphere in term of non-equilibrium chemistry?

**Process:** same input temperature profile computed by Exo-REM (without clouds) for two sets of characteristic corresponding to potential targets at chemical equilibrium and for a strong Eddy coefficient $K_{eddy}$, defining non-equilibrium chemistry with two chemical networks (Venot et al. 2012 and Exo-REM adapted form Zahnle and Marley 2014)

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**Non-equilibrium chemistry:**
Non-equilibrium chemistry can strongly affect the composition at observable levels of relatively cold atmospheres, originate from vertical transport from deep but layers where chemical equilibrium is achieved. When the dynamical timescales (triggered by Eddy coefficient $K_{eddy}$) is shorter than the chemical timescales we observe a freezing of the abundances of some species.

**Uncertainties on the chemical network:** Exo-REM takes into account some condensation when Venot et al. 2012 don’t decide to apply a modification of the initial elemental abundances used in Venot model, corresponding to a depletions of ~0.99 of the amount of oxygen in silicate. We observe other differences, without identifying the origin, such as more methane and loss water up to 1 bar in Venot et al. 2012, but without strong impact in spectra.

**Conclusions:**
- JWST will allow us to explore some physical condition of young giant exoplanet such as the non-equilibrium chemistry effect.
- In the MIR CH$_4$, CO$_2$ and NH$_3$ impact spectra and will give constrains to discriminate those effects.
- 4QPM will give constrains on abundances of the NH$_3$ for the major part of already known direct imaged exoplanets.
- NIRSpec observation will be useful to discriminate equilibrium/non-equilibrium.

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